Satellite Mission Update: Water Resource Applications

Water Resources Program Review

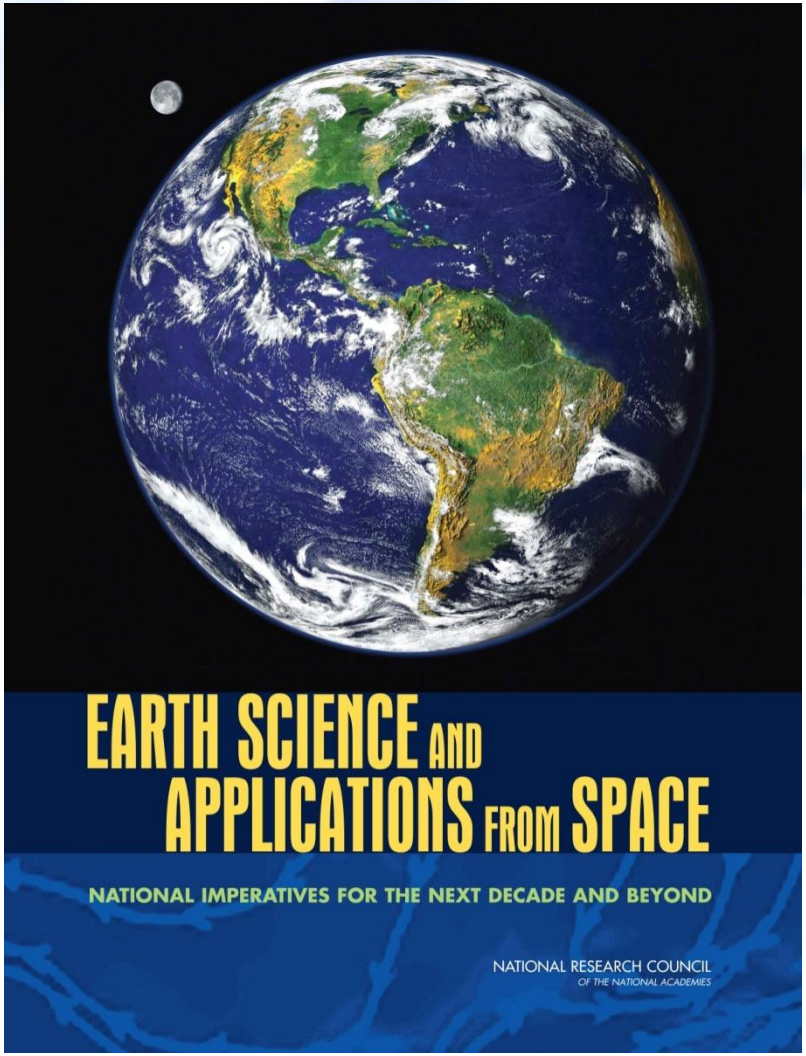
6 September 2012

Earth Science & Applications

Decadal Survey

The national strategy outlined here has as its overarching objective a program of scientific discovery and development of applications that will enhance economic competitiveness, protect life and property, and assist in the stewardship of the planet for this and future generations.

Earth Science *Decadal Survey*



Earth Science & Applications

Guidelines for Mission Planning

BOX 5.1 GUIDELINES FOR MISSION PLANNING TO BALANCE SCIENCE AND APPLICATIONS

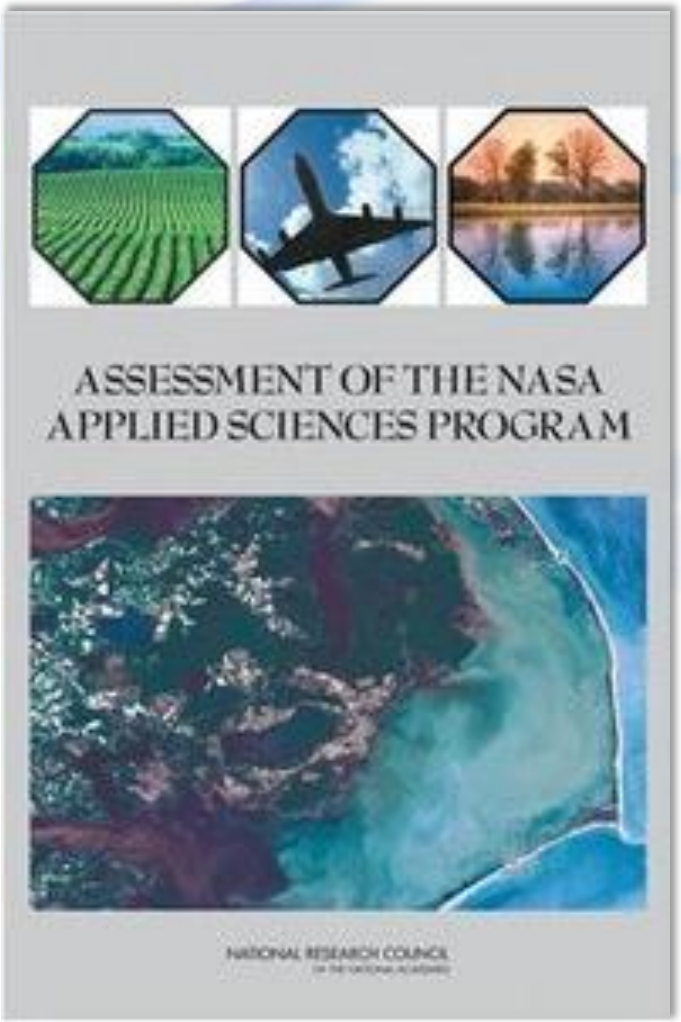
- Processes to move from observations to information should be identified in the initial planning of new missions.
- Mission planning should consider performance requirements for applications, such as timeliness of and capacity for data integration.
- Planning should consider the need for ancillary data and should ensure that ancillary data are available when needed.
- Planning and implementation priorities should include the need to link the data to models and decision-support tools and processes.
- Planning should provide effective lines of communication between decision makers and data gatherers.

Applied Sciences Program

Program Assessment

Recommendation (one of five)

RECOMMENDATION 1: ASP should be assigned the responsibility within NASA to review and help establish the requirements and guidelines offered in Chapter 5 of the Decadal Study for effective extension of data and research to applications that meet societal needs. As part of this action, the committee recommends incorporating an ASP representative on NASA mission design and selection teams to aid ASP in increasing the use and impact of NASA products in the user community.



NAS, 2007

Earth Science & Applications

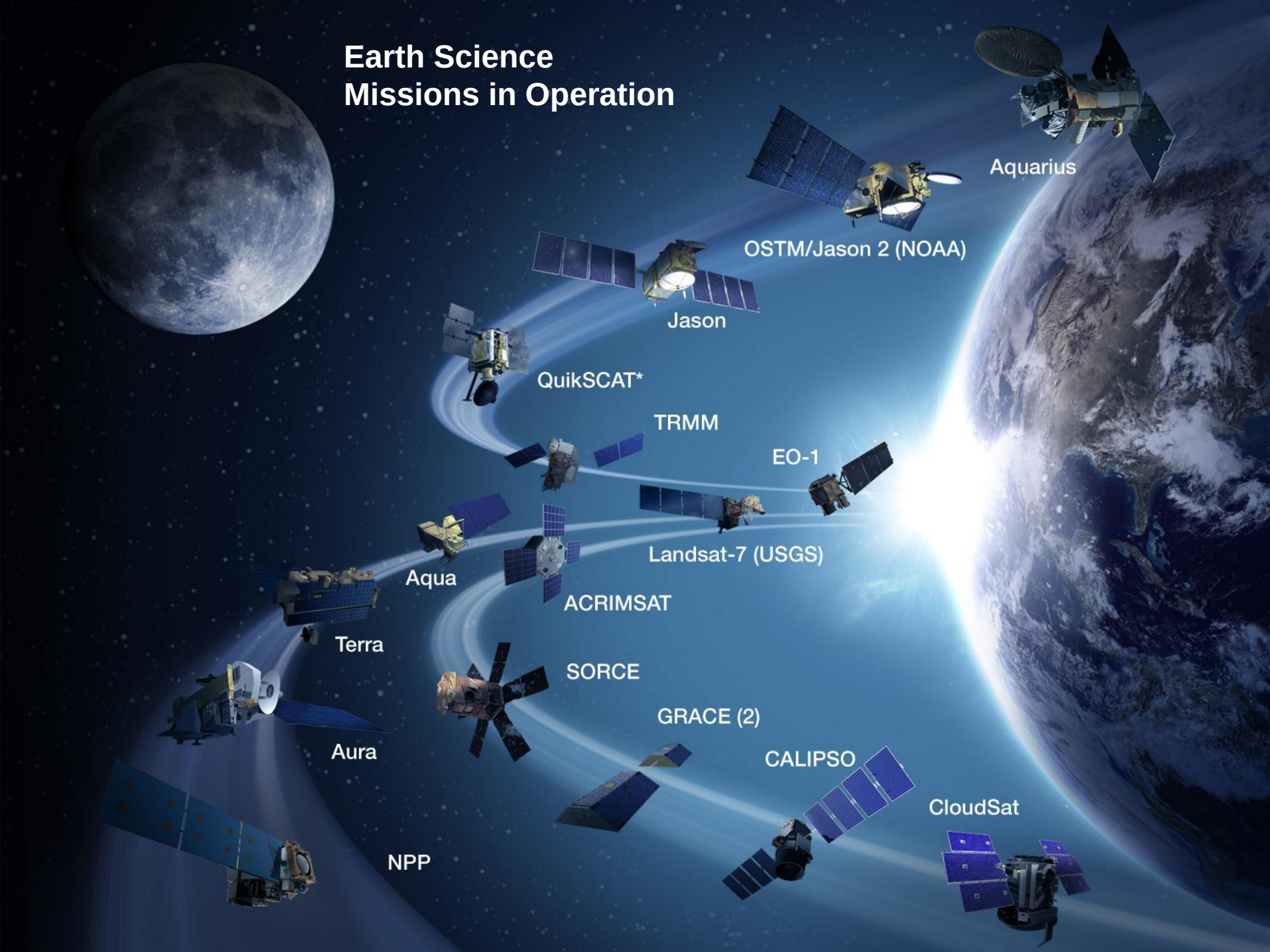
Program Applications Reps.

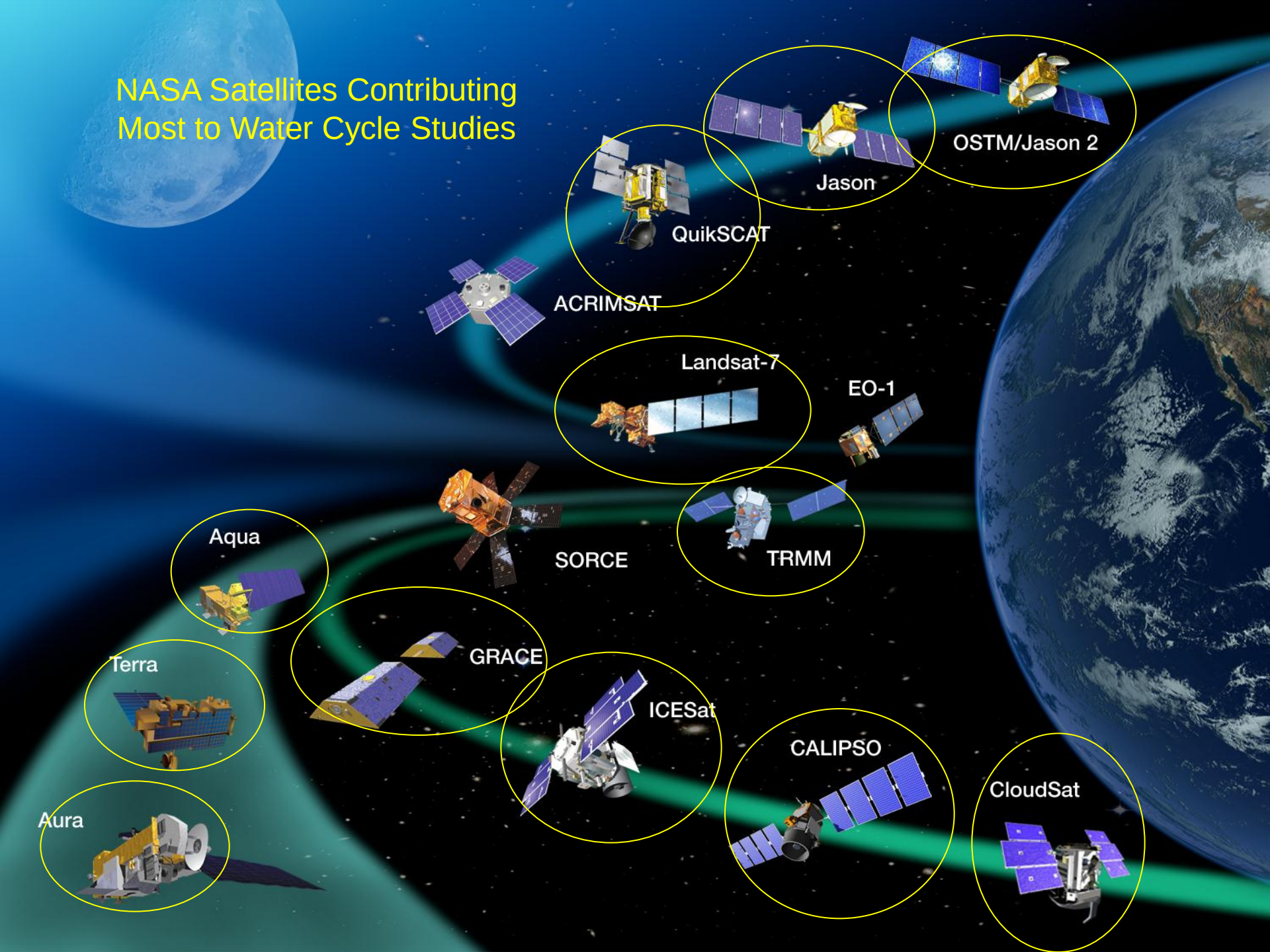
Center Mission Applications Representatives *(Program level)*

Key Responsibilities:

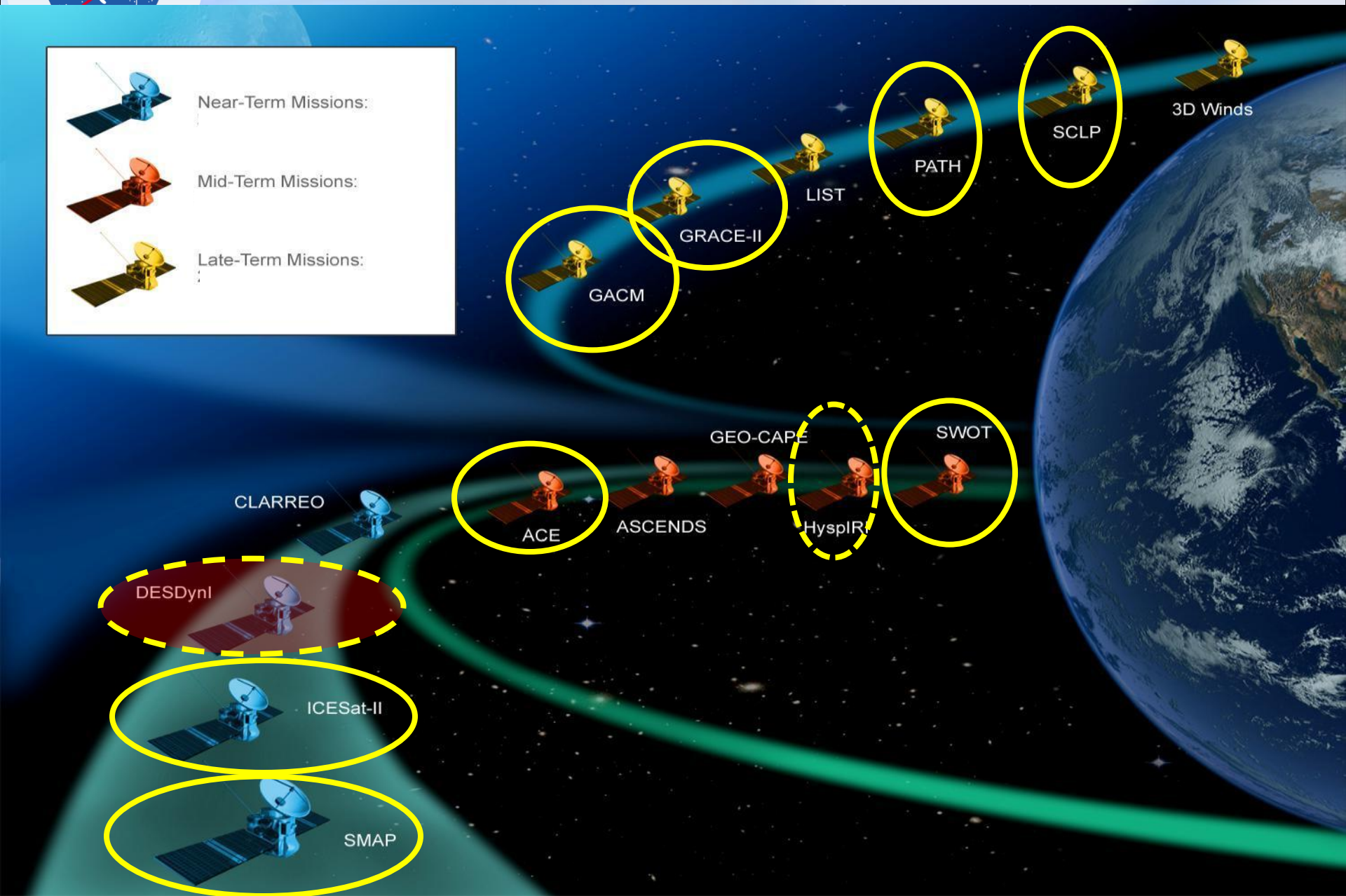
- Work with the HQ Program Manager to represent Applications perspectives in the mission development and planning; help in support to PE & PS
- Participate in regular telecons and team meetings for the mission.
- Engage with the mission project and SDT/ST, with an emphasis on the applications and scientific aspects of the mission.
- Support Mission Project team to develop the applications dimension of mission
- Organize the relevant applications communities on behalf of the mission they represent. Support and facilitate organizations' and communities' efforts to imagine, articulate, and anticipate possible applications. Organize sufficient meetings/events/workshops to support and organize the applications communities for the mission
- Enhance the applications value of mission and alert management to situations in which the applications value of the mission might increase/decrease

NOTE: These reps are not the Applications Lead at the Project-level.


Earth Science
Missions in Operation
Aquarius
OSTM/Jason 2 (NOAA)
Jason
QuikSCAT*
TRMM
EO-1
Landsat-7 (USGS)
Aqua
ACRIMSAT
Terra
SORCE
GRACE (2)
Aura
CALIPSO
CloudSat
NPP


NASA Satellites Contributing
Most to Water Cycle Studies
OSTM/Jason 2
Jason
QuikSCAT
ACRIMSAT
Landsat-7
EO-1
SORCE
TRMM
Aqua
GRACE
Terra
ICESat
CALIPSO
CloudSat
Aura

Decadal Survey Missions Next Generation

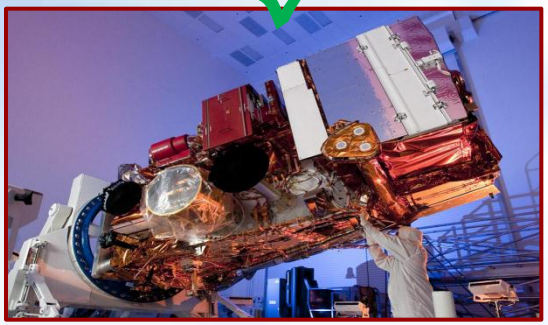


Integrated Program for Water Availability/Quality

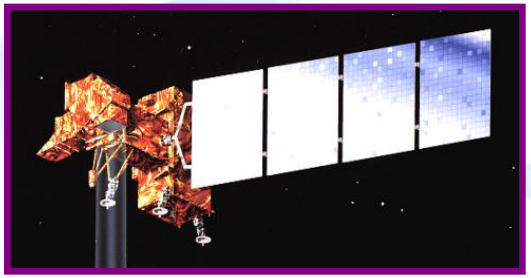
- **Precipitation**
  - TRMM (extended mission w/JAXA); Field Campaigns (e.g. GRIP,
  - EV-1 HS3; GPM (2014 w/ JAXA)
- **Soil Moisture and Freeze/Thaw State**
  - SMAP (w/CSA)
- **Inland Waters**
  - SWOT (late 2019 w/CNES, CSA)
- **Subsurface Ground Water (Aquifer Volume Changes)**
  - GRACE and GRACE-FO (2016 w/Germany)
- **Glacier and Ice Sheet Volume Changes and Dynamics**
  - ICEBRIDGE (ongoing); ICESAT-2 (2016); DESDynI (TBD)
- **Coastal Water Quality**
  - PACE (2019/2020 w/ CNES [likely])
- **Northern Latitude Land, Lakes, Permafrost**
  - EV-1 CARVE, SMAP, SWOT, GRACE-FO, ICESAT-2, DESDynI
- **Accelerated Operational Use of Research Measurements, …**

Missions in Formulation and Implementation

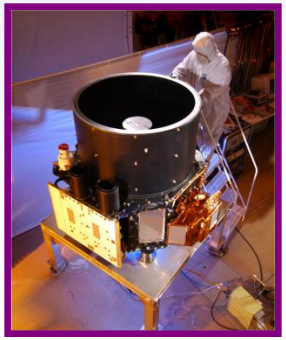
AQUARIUS
6/10/2011
w/CONAE; SSS



NPP
10/25/2011
w/NOAA
EOS cont., Op Met.



LDCM
02/2013
w/USGS; TIRS



ICESat-2
April 2016
Ice Dynamics

SMAP
Late CY2014
w/CSA
Soil Moist., Frz/Thaw

GPM
7/2013 (TBR)
w/ JAXA; Precip

OCO-2
2013
Global CO_2

Applications Lead– Doorn
DPAs – Molly Brown, GSFC
And Son Nghiem, JPL

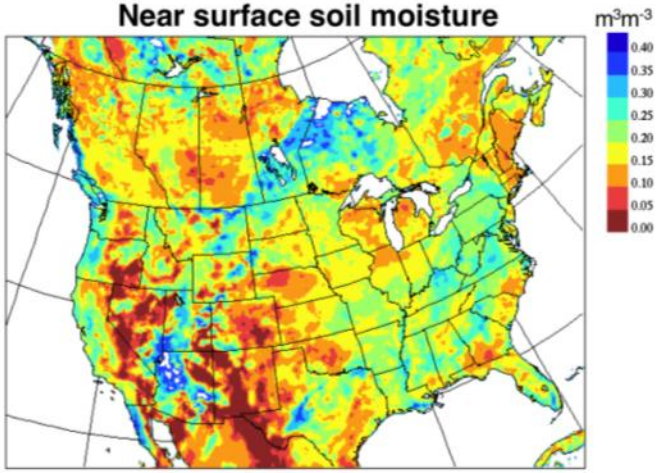
The NASA Soil Moisture Active Passive (SMAP) Mission: Drought Monitoring

….global mapping of soil moisture at a 10-km spatial resolution with a 2-3 day revisit time

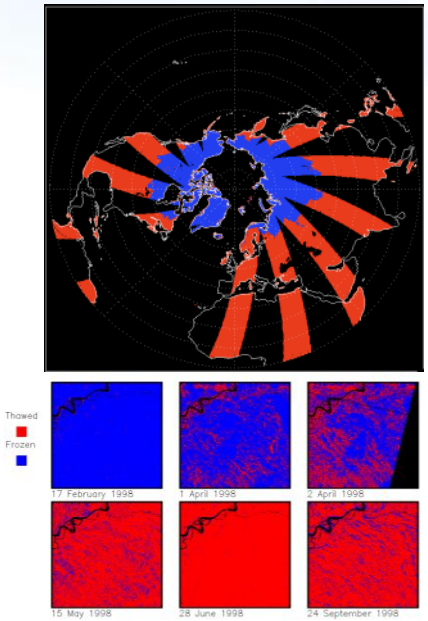
Science Objectives

SMAP will provide high-resolution, frequent-revisit global mapping of soil moisture and freeze/thaw state to enable science and applications users to:

- Understand processes that link the terrestrial water, energy and carbon cycles
- Estimate global water and energy fluxes at the land surface
- Quantify net carbon flux in boreal landscapes
- Enhance weather and climate forecast skill
- Develop improved flood prediction and drought monitoring capability



Freeze/thaw state



SMAP Data Products

Data Product Short Name	Description	Data Resolution	Grid Spacing	Mean Latency*
L1B_S0_LoRes	Low Resolution Radar σ_o in Time Order	5x30 km (10 slices)	-	12 hrs
L1C_S0_HiRes	High Resolution Radar σ_o on Swath Grid	1x1 km to 1x30 km	1 km	12 hrs
L1B_TB	Radiometer T_B in Time Order	36x47 km	-	12 hrs
L1C_TB	Radiometer T_B	40 km	36 km	12 hrs
L2_SM_A	Radar Soil Moisture*	1-3 km	3 km	24 hrs
L2_SM_P	Radiometer Soil Moisture	40 km	36 km	24 hrs
L2_SM_A/P	Active-Passive Soil Moisture	9 km	9 km	24 hrs
L3_F/T_A	Daily Global Composite Freeze/Thaw State	1-3 km	3 km	50 hrs
L3_SM_A	Daily Global Composite Radar Soil Moisture	1-3 km	3 km	50 hrs
L3_SM_P	Daily Global Composite Radiometer Soil Moisture	40 km	36 km	50 hrs
L3_SM_A/P	Daily Global Composite Active-Passive Soil Moisture	9 km	9 km	50 hrs
L4_SM	Surface and Root Zone Soil Moisture	9 km	9 km	7 days
L4_C	Carbon Net Ecosystem Exchange	9 km	9 km	14 days

*** Mean latency under normal operating conditions. Latency defined as time from data acquisition by instrument to availability to designated data archive. The SMAP project will make a best effort to reduce these latencies. [*research product]**

SMAP
Soil Moisture Active & Passive

Applications Working Group (AppWG)

SMAP has the potential to enable a diverse range of applications including drought and flood guidance, agricultural productivity estimation, weather forecasting, climate predictions, human health risk, and defense systems. Applications across agencies are a unique feature of SMAP. Some of these applications are summarized on the Applications page.

Planning for SMAP applications has been initiated to identify early adopters, current partners, and future potential users of SMAP data. A SMAP Applications Working Group (AppWG) has been formed that includes the following objectives:

- Assess current applications benefits and requirements for SMAP products
- Develop a community of end-users that understand SMAP capabilities and are interested in using SMAP products in their application
- Target partners who can work with the SMAP project during the pre-launch period, particularly to assess impacts on their applications
- Provide information about SMAP to the broad user community

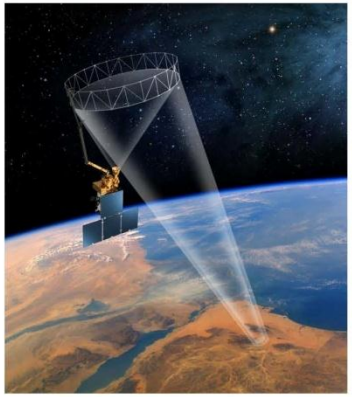
SMAP AppWG activities will be carried out mainly through emails and telecons. The AppWG will also take advantage of member attendance at conferences such as AGU and IGARSS to meet in person when possible.

Mission Application Plan

Preliminary

National Aeronautics and Space Administration
Goddard Space Flight Center, Greenbelt, MD

Soil Moisture Active Passive (SMAP) Mission Applications Plan



Edited by:

Molly Brown[1], Susan Moran[2], Vanessa Escobar[3], Dara Entekhabi[4]

[1]SMAP Applications Coordinator, [2]SMAP Applications Working Group Chair, [3]Deputy SMAP Applications Coordinator, [4]SMAP Science Definition Team Leader

11 August 2011

Summary of Activities

between

the Soil Moisture Active Passive (SMAP) Project[1]
NASA Jet Propulsion Laboratory

and

International Research Institute for Climate and Society (IRI)
The Earth Institute at Columbia University

for

SMAP Applications Early Adopter activities related to

SMAP for Crop Forecasting and Food Security Early Warning Applications

Approved by:

Eni Njoku 8/15/11
Eni Njoku [Date]
SMAP Project Scientist
JPL

Stephen Zebiak [Date]
Director General
International Research Institute
for Climate and Society (IRI)

Jared Entin [Date]
SMAP Program Scientist
NASA Headquarters

Juliana Powell [Date]
Assistant Director, Morningside
Columbia University

Brad Doorn [Date]
Applied Sciences Program Manager
NASA Headquarters

[1] The SMAP mission has not been approved by NASA. The decision to proceed with the mission will not occur until the completion of the National Environmental Policy Act (NEPA) process.

Signed Early Adopter Agreement

SDT Engagement with SMAP Early Adopters

Associated each EA with a SMAP SDT member or Project Affiliate to assist EA in applications research and report quantitative results at SDT meetings

Data Provided to SMAP EAs

Simulated SMAP Products[1]
L1C_Radar
L1B_Radiometer
L1C_Radiometer
L2_SM_A
L2_SM_P
L2_SM_A/P
L3_F/T_A
L3_SM_A
L3_SM_P
L3_SM_A/P
L4_SM
L4_C
Cal/Val Data
In Situ Sparse Network Data
Field Campaign Data

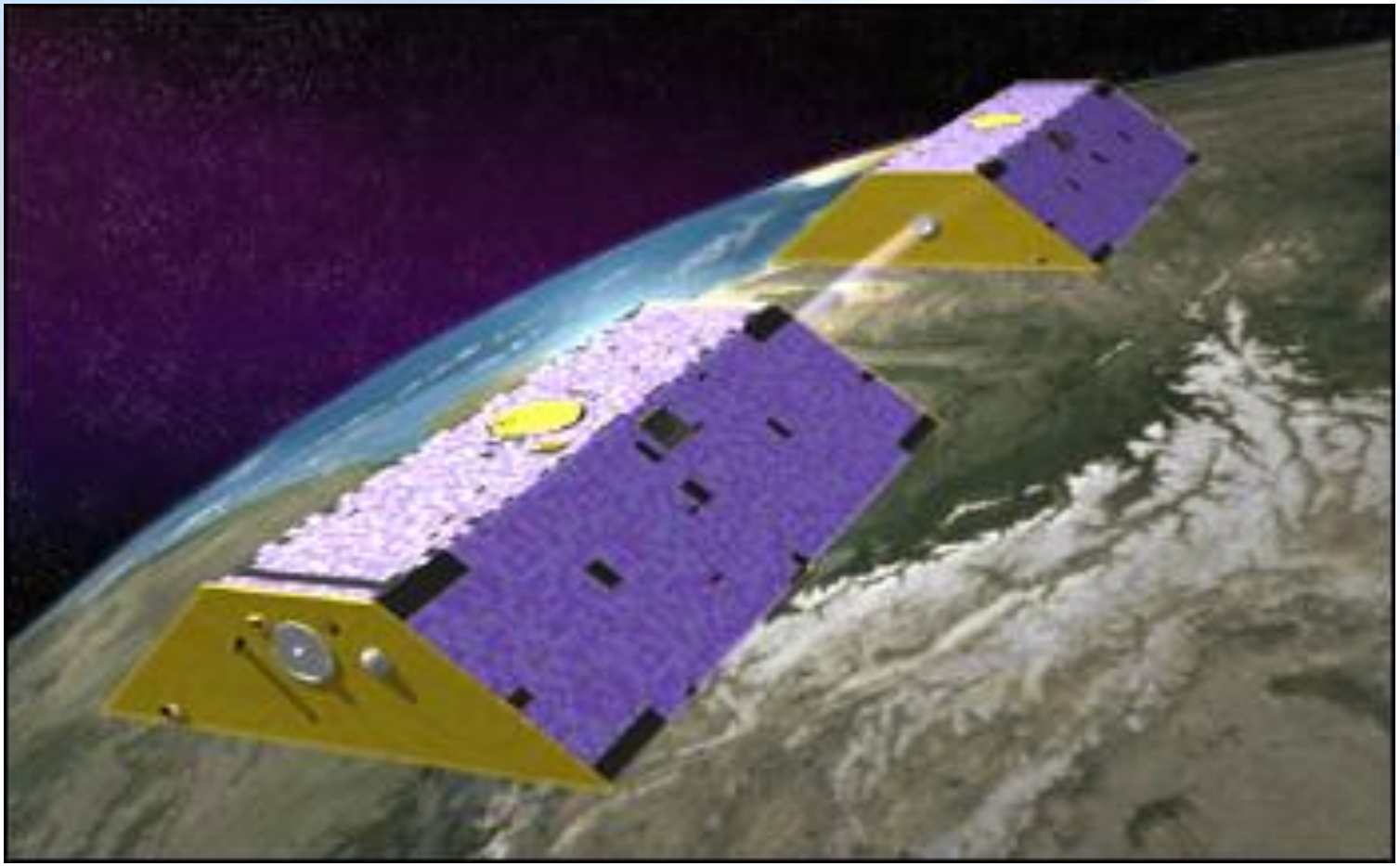
SMAP SDT/EA PreLaunch Collaborative Teams

Early Adopter PI and Institution	SMAP Project Partner
Selected in 2011	
Stephane Belair, Meteorological Research Division, Environment Canada (EC)	Stephane Belair
Hosni Ghedira, Masdar Institute, UAE	Dara Entekhabi
Zhengwei Yang and Rick Mueller, USDA National Agricultural Statistical Service (NASS)	Wade Crow
Catherine Champagne, Agriculture and Agri-Food Canada (AAFC)	Stephane Belair
Amor Ines and Stephen Zebiak, International Research Institute for Climate and Society (IRI) Columbia University	Narendra Das
Lars Isaksen and Patricia de Rosnay, European Centre for Medium-Range Weather Forecasts (ECMWF)	Patricia de Rosnay
Xiwu Zhan, Michael Ek and John Simko, NOAA National Environmental Satellite Data and Information Service, Center for Satellite Applications and Research (NOAA-NESDIS-STAR)	Randy Koster

Early Adopter PI and Institution	SMAP Project Partner
Selected in 2012	
Curt Reynolds, USDA Foreign Agricultural Service (FAS)	Wade Crow
John Eylander, U.S. Army Engineer Research and Development Center (ERDC) Cold Regions Research and Engineering Laboratory (CRREL)	Susan Moran
Jim Reardon and Gary Curcio, US Forest Service (USFS)	Dara Entekhabi
Gary McWilliams, Li Li, Andrew Jones and George Mason, Dept. of Defense - Soil Moisture Applications Consortium (SMAC)	Susan Moran
Michael Ek, Marouane Temimi, Xiwu Zhan, NOAA National Centers for Environmental Prediction (NCEP)	Kyle McDonald
John Galantowicz, Atmospheric and Environmental Research, Inc. (AER)	John Kimball
Jingfeng Wang, Rafael Bras and Aris Georgakakos, Georgia Institute of Technology (GIT)	Dara Entekhabi
Don Pierson, New York City Dept. of Environmental Protection	Kyle McDonald
Chris Funk, Amy McNally and James Verdin, US Geological Survey & UC Santa Barbara	Molly Brown
Fiona Shaw, Willis, Global Analytics	Robert Gurney
Rafael Ameller, StormCenter Communications, Inc.	Randy Koster

GRACE and GRACE-FO

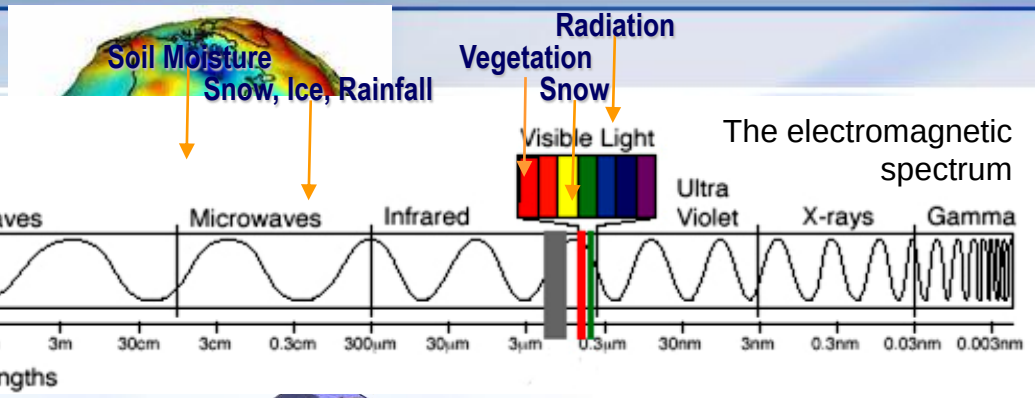
Application PM – Doorn, DPA – Erik Ivins, JPL; John Bolten, GSFC



Gravity Recovery and Climate Experiment

Improving Ground Water Estimates

Aqua:
MODIS,
AMSR-E,
etc.



Traditional radiation-based remote sensing technologies measure water in the upper few centimeters of soil or vegetation or snow, including changes in groundwater levels

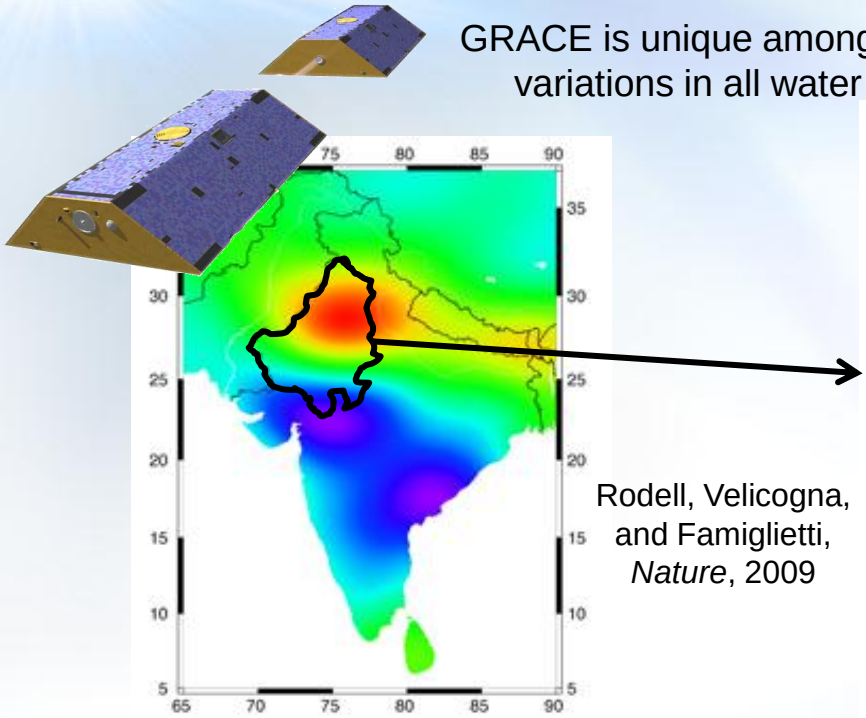
These precise gravity measurements are used to infer the total wetness of the land surface

Matthew.Rodell@nasa.gov

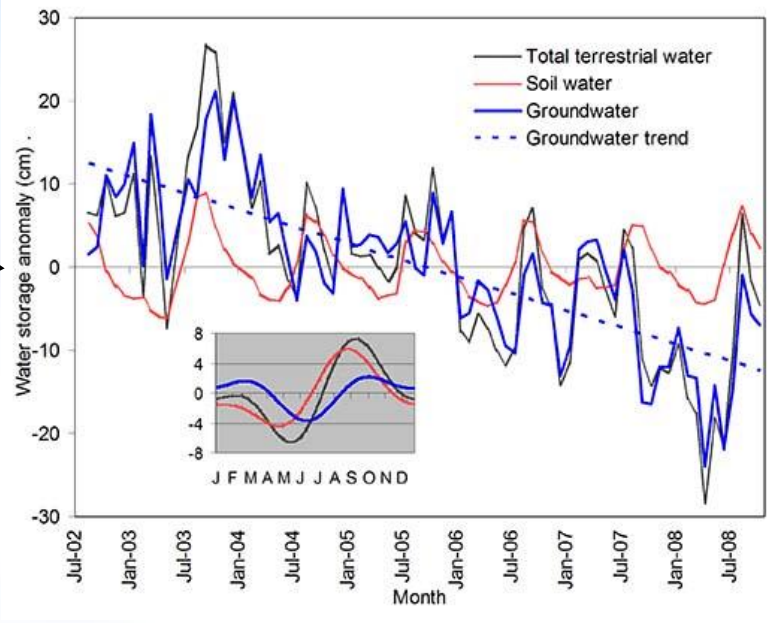
GRACE Reveals Massive Depletion of Groundwater in NW India

The water table is declining at an average rate of 33 cm/yr

GRACE is unique among Earth observing missions in its ability to monitor variations in all water stored on land, down to the deepest aquifers.



Rodell, Velicogna, and Famiglietti, *Nature*, 2009



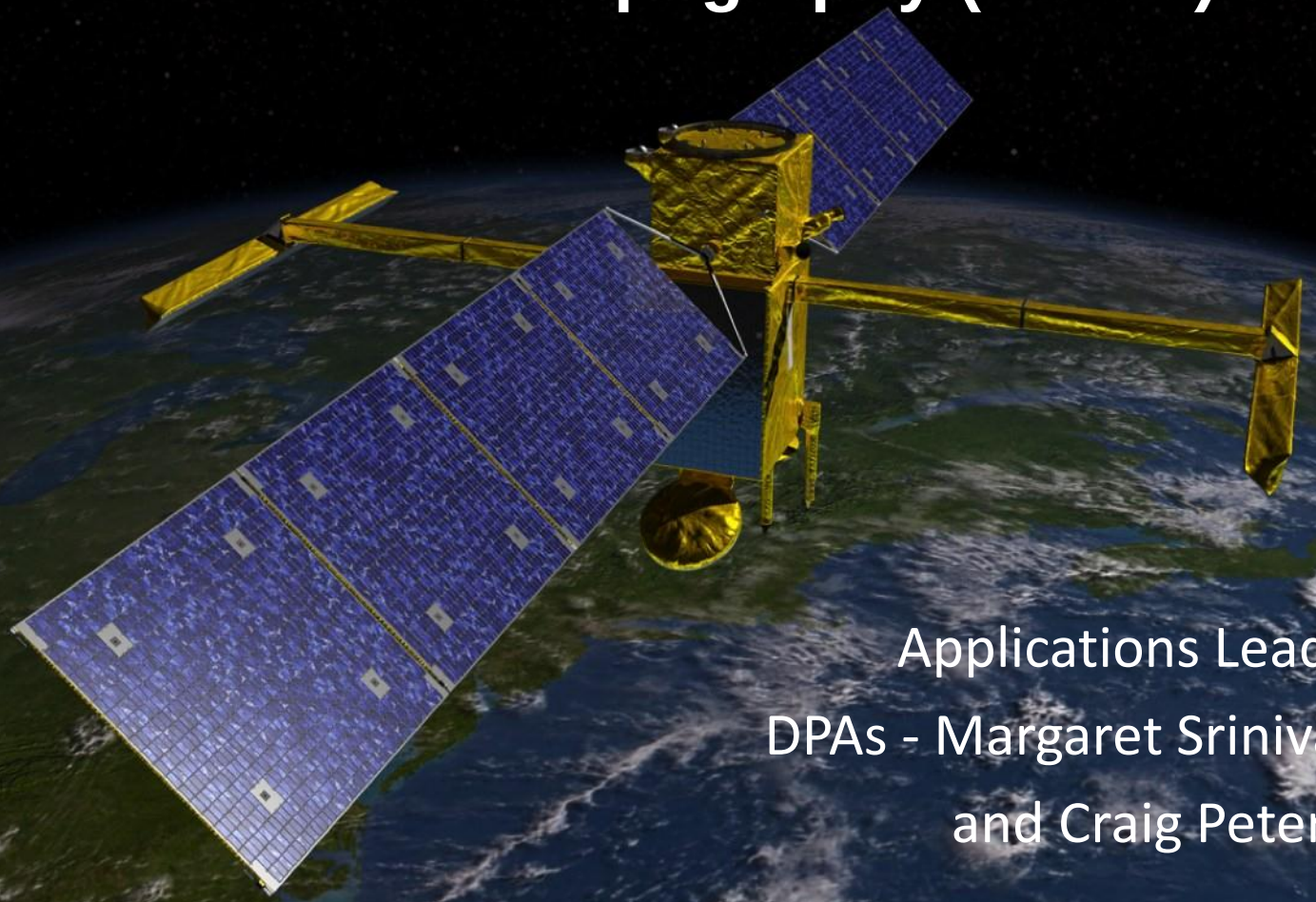
Trends in groundwater storage during 2002-08, with increases in blue and decreases in red. The study region is outlined.

Time series of total water from GRACE, simulated soil water, and estimated groundwater, as equivalent layers of water (cm) averaged over the region. The mean rate of groundwater depletion is 4 cm/yr. Inset: Seasonal cycle.

During the study period, 2002-08, 109 km^3 of groundwater was lost from the states of Rajasthan, Punjab, and Haryana; triple the capacity of Lake Mead

Matthew.Rodell@nasa.gov

Surface Water and Ocean Topography (SWOT) Mission



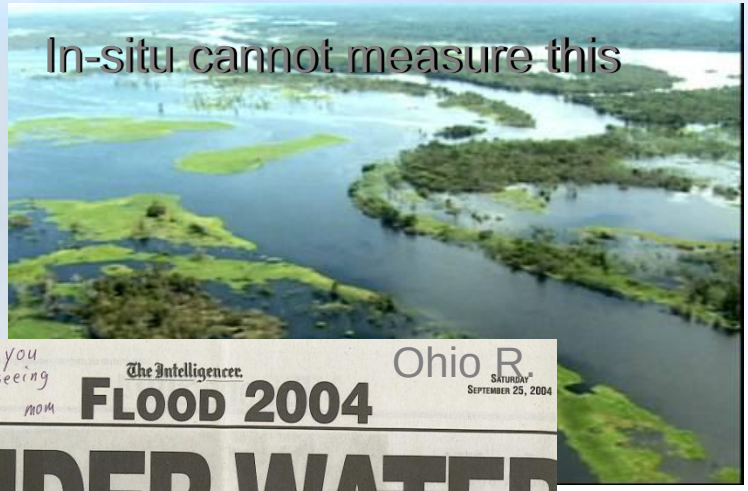
Applications Lead - Doorn

DPAs - Margaret Srinivasan, JPL

and Craig Peterson, SSC

SWOT
Surface Water Ocean Topography

1. The Problem

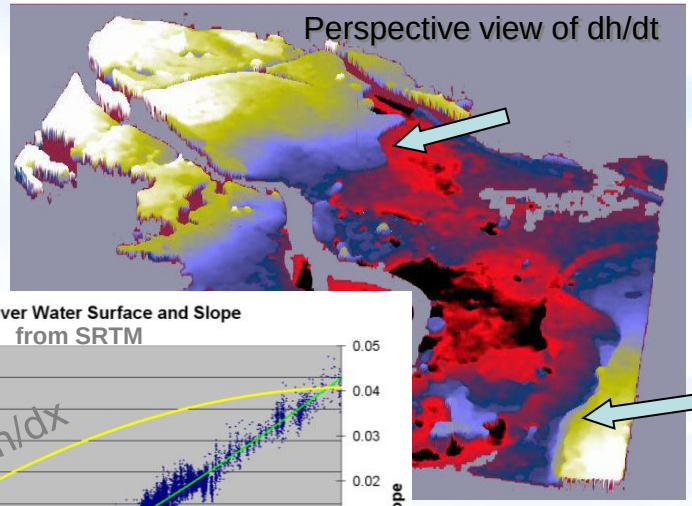


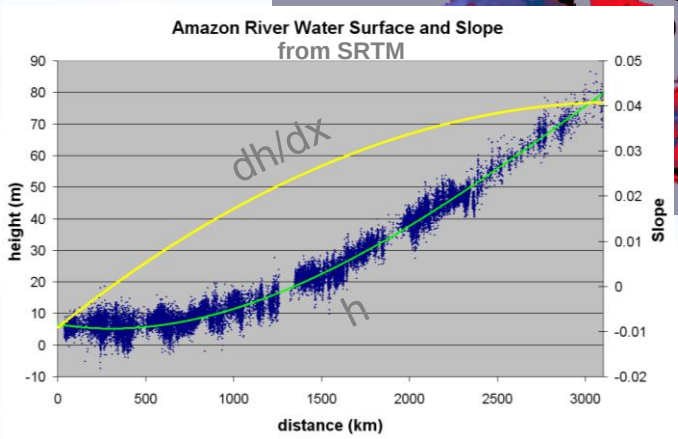
Ohio R.

Floods are the number one hazard

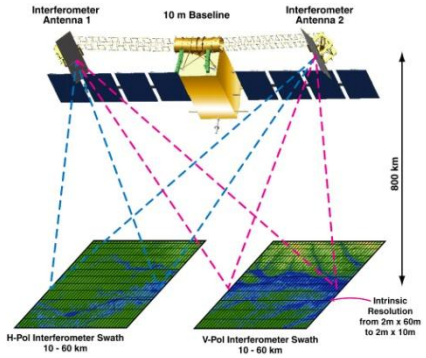
2. The Question
What is the spatial and temporal variability of freshwater stored in the world's terrestrial water bodies?

3. Measurements Required
maps of h, which give maps of dh/dt and dh/dx



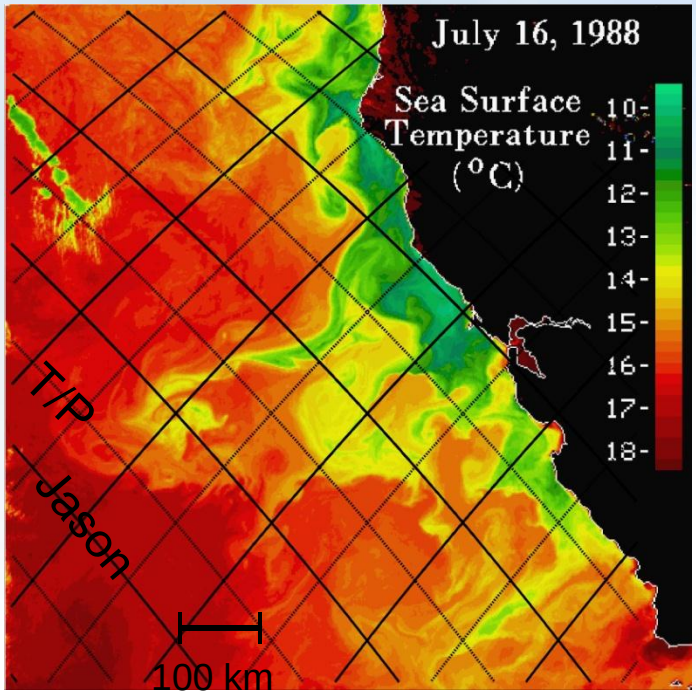


4. The Solution
KaRIN: Ka-band Radar Interferometer. SRTM, WSOA heritage. Maps of h globally and ~weekly.



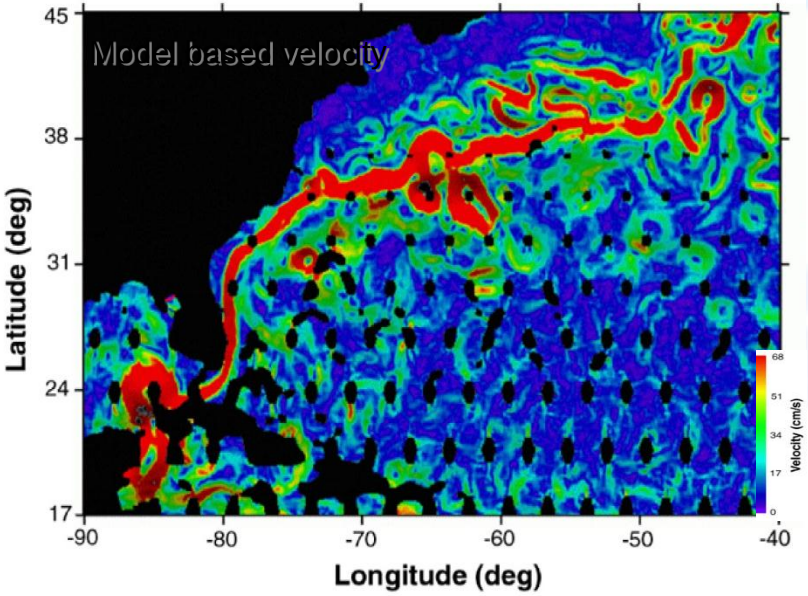
SWOT
Surface Water Ocean Topography

1. The Problem Altimeters miss considerable ocean area.



2. The Question What are the energy dissipation, ocean circulation, and climate implications from oceanic eddies which contain 90% of the kinetic energy, but are ~10 km scale in cross-stream direction, e.g. Gulf Stream, Kuroshio.

3. Measurements Required **Maps of h, which give maps of dh/dt and dh/dx allowing derivation of velocity, vorticity, and stress tensor.**



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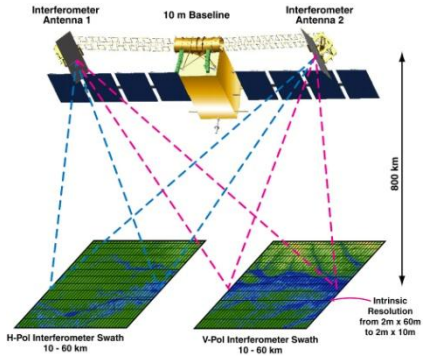


NASA ESD Applied Sciences Program

NASA supports applications activities for early phase missions based on Earth Science Decadal Survey (NRC, 2007)

➔ SWOT – Tier 2 Decadal Survey mission

SWOT mission has mature Applications approach at the project level, supported by NASA HQ & science team

NASA ESD Applied Science Program

Lawrence Friedl, SMD ES Applied Science Director

Bradley Doorn, Program Manager for Agriculture, Carbon & Water Resources

Project-level

Margaret Srinivasan, (JPL), SWOT Deputy Program Applications Leads

Craig Peterson (Stennis), SWOT Deputy Program Applications Leads

External advisors

Dr. Ed Beighley, FM Global

Faisal Hossein, University of Tennessee

Science Team

All

Mission Applications Concentrations

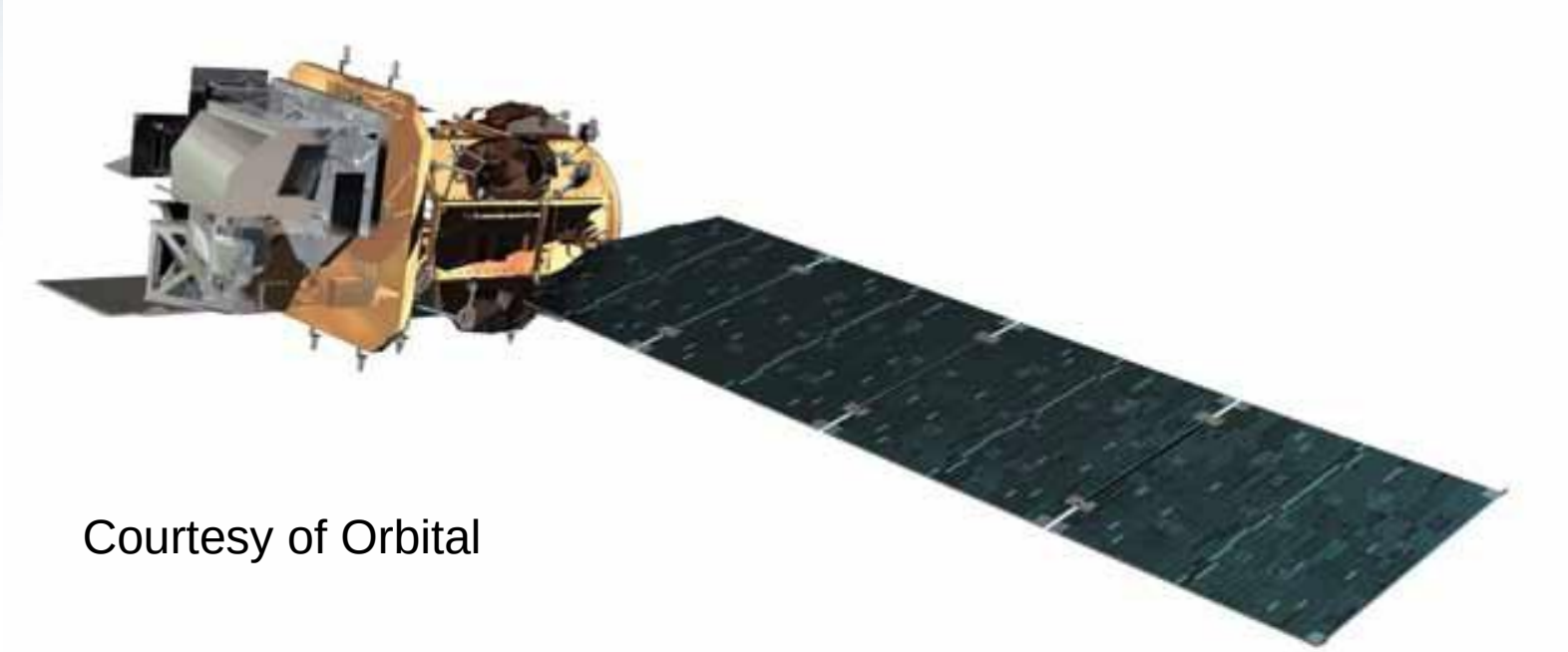
- **Hydrology – Storage & water discharge on land**
- **Ocean – Improved mesoscale & submesoscale processes**

Strong Satellite Radar Altimeter
Application User Community Already Exists

- Water management: reservoirs, floods, ecology
- International rivers: flood and drought management
- Insurance: hydrodynamics and flood risks
- Transportation: shipping, barges
- Agriculture: water management to support irrigation
- Energy: water availability in new regions
- Spills and pollution: mapping of potential spill
- Ocean and coastal circulation models
- Climate studies: ocean circulation, heat content, regional sea level studies
- Operational users support: NOAA, Navy…

Landsat Data Continuity Mission (aka Landsat 8)

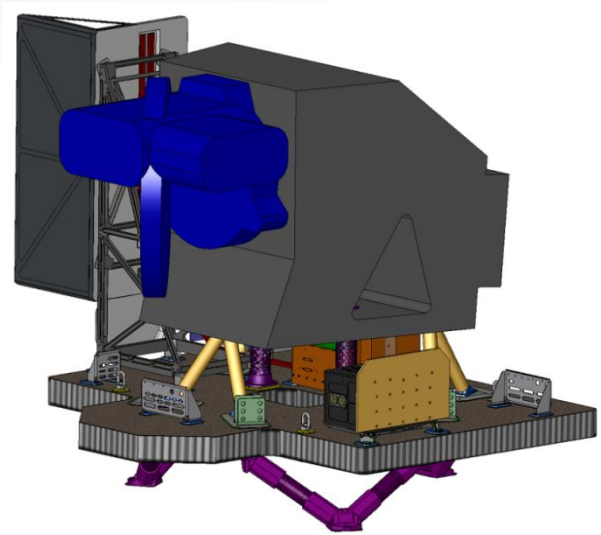
- The Landsat Data Continuity Mission (LDCM) is under development for a December, 2012 launch
  - Developed as a NASA / USGS partnership
  - LDCM conducted a successful critical design review (CDR) May 25 – 27, 2010



Courtesy of Orbital

Operational Land Imager

- Pushbroom VIS/SWIR sensor
- Four-mirror telescope with front aperture stop
- FPA consisting of 14 sensor chip assemblies, passively cooled
- 9 spectral bands in visible and near-infrared
- Onboard lamp & dark calibration plus solar and lunar cal views
- 5 year design life, Risk Class B



- Key instrument parameters
  - Cross-track FOV 185 km
  - Geodetic accuracy
    - Absolute 65 m
  - Band to Band Registration 4.5 m

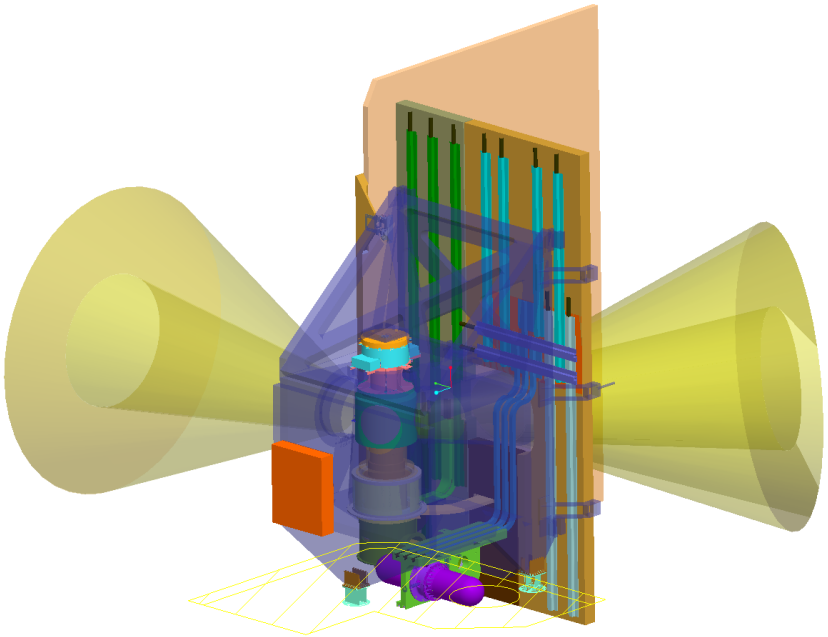
Band Name	Band (nm)	Bandwidth (nm)	GSD (m)	SNR
Coastal/ Aerosol	443	20	30	130
Blue	482	65	30	130
Green	562	75	30	100
Red	655	50	30	90
NIR	865	40	30	90
SWIR 1	1610	100	30	100
SWIR 2	2200	200	30	100
PAN	590	180	15	80
Cirrus	1375	30	30	50

Visible/NIR SWIR

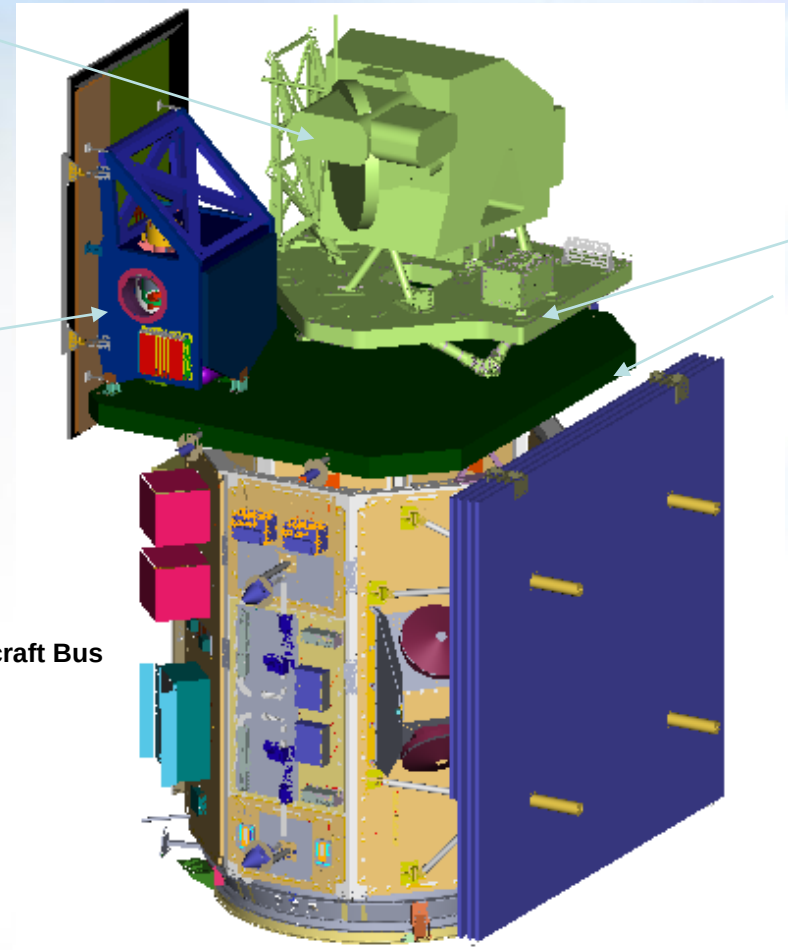
Thermal Infrared Sensor

- Pushbroom design with scene select mirror to select between calibration sources
- Quantum Well Infrared Photodetector (QWIP) detector/FPA
- 2 channel (10.8 and 12 um) thermal imaging instrument
- Two full aperture cal sources: onboard variable temp black body and space view
- Passively cooled telescope assembly operating at 180K
- Actively cooled (cryocooler) FPA operating at 43K
- 3 Year Design Life, Class C Instrument

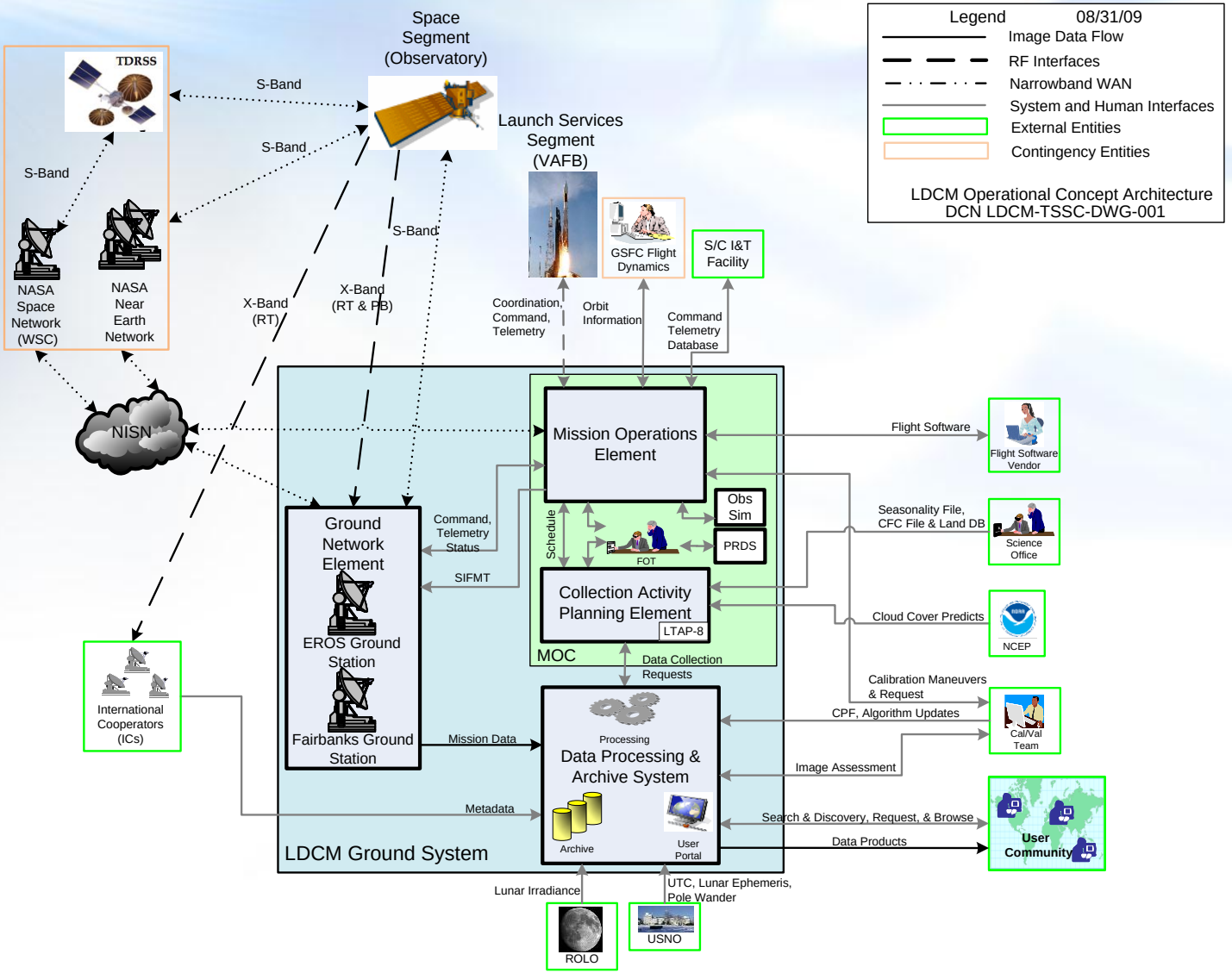
- Key Performance Parameters
  - Cross-track FOV 185km
  - Geodetic accuracy
    - Absolute 76 m
  - Band To Band Registration 18m
  - GSD 120M
    (100m nominal)



Observatory



Ground System



Launch Vehicle

- Launch from Vandenberg Air Force Base on an Atlas V

LDCM Status Summary

- Continuity with previous Landsat missions is fulfilled by LDCM
  - LDCM data will be comparable to data from previous Landsat satellites
  - Data collection along heritage orbital paths with identical 185 km swath width
  - Ensure global coverage of land mass on seasonal basis
  - LDCM data will be backward compatible with data from previous Landsat sensors
    - Supports long term retrospective studies to trend change over time
- Capabilities are advanced
  - Two new reflective bands, refined band widths avoid atmospheric absorption features, two thermal bands facilitate atmospheric correction
  - Improved performance
  - More data – 400 scenes per day lead to improved global coverage
- USGS will distribute LDCM data free to the general public
  - Capabilities to process and analyze large volumes of Landsat data are advancing rapidly for long term and broad area studies
- On Schedule for a Feburary 2013 launch

DRAFT

As Aug 7, 2012

Hydrology Applications Joint Mission Tutorial for SMAP with GPM, GRACE-FO & SWOT

Hosted by
USGS National Center
12201 Sunrise Valley Dr. Reston, VA 20192

October 17-18, 2012

This unique joint tutorial will explore the collaborative opportunities for the future use of SMAP, GPM, GRACE Follow-On (FO) and SWOT data with existing satellite observation capabilities. This effort will create a platform for joint mission research, prepare users for future mission data, identify collaborators for pre-launch efforts and identify topics where remote sensing data can help improve operational products used for policy, management and decision-making in water resource management.

Goals of the workshop:

- Identify a large target audience for multi sensor Hydrology data.
- Understanding the needs for soil moisture and other NASA data in various fields of Hydrology
- Merging missions in order to address the broad needs of hydrology and water management
- Identify data models and research where SMAP, GPM, GRACE FO and SWOT can help address climate and hydrology policy questions
- Promote Early Adopter research and collaboration opportunities

DAY 1	**Wednesday, October 17, 2012 (Presentations and Break-outs)**	
8:00am	**Registration and Coffee**	
8:30am	Jared Entin, NASA HQ *(15 min)*	Workshop Welcome
8:45am	USGS Representative (VIP) *(15 min)*	Welcome to USGS
9:00am	Molly Brown, NASA GSFC *(10 min)*	NASA Applications Requirements and strategy
9:10am	Dara Entekhabi, MIT *(15 min)*	SMAP Mission Overview
9:25am	Arthur Hou, NASA GSFC *(15 min)*	GPM Mission overview
9:40am	Matt Rodell, NASA GSFC *(15 min)*	GRACE Mission overview
9:55am	Doug Alsdorf, Ohio State University *(15 min)*	SWOT Mission Overview
10:10am	Molly Brown, NASA GSFC *(10 min)*	Define Joint Tutorial Objectives
Morning Break 10:10am to 10:20am (Please take time to fill out your surveys)		
Part 1: Proposed presentation topics that provide a brief description of anticipated mission products (current and future) and their potential applications to hydrology and water management *(15 min per presentation) Speakers have not yet been confirmed*		
	Client/User/researcher	*Sample Presentation Category*
10:20am	*Speaker confirmation pending*	*Hydrology of inland water using SMAP and ICESat-2 data.*
10:35am	*Speaker confirmation pending*	*Hydrology, Transnational River Boundaries and SWOT*